# Influence of process parameters on tool wear in turning of Ti-6Al-4V alloy

[1]J. Viswashekar, P.G. Student, VNRVJIET, Hyderabad, India.
[2]M. VenkataRamana, Professor, VNRVJIET, Hyderabad, India.
[1]viswajagarlamudi@gmail.com, [2]venkataramana_m@vnrvjiet.in

Abstract - **Titanium alloy is difficult to machine due to its poor machinability properties such as low thermal conductivity, elevated stress and high cutting temperature. The high cutting temperature leads to accelerate the tool wear which results short tool life and low productivity. Cutting fluids are used to reduce the cutting temperature produced at contact area between work piece and cutting tools. By using coolants, cost of the machining increases and it is hazardous to the operator. In order to reduce the cost of production minimum quality lubrication system is used for machining operation. The experimental investigation are conducted in this work to analyze the effect of machining parameters like (speed, feed, and depth of cut) and MQL parameters like (pressure, stroke volume, stroke time and oil proportion factor) on tool wear with uncoated carbide tools while turning of titanium alloy and chip formation. The cutting fluids are prepared by blending of two different oils such as (Rice bran and LRT oil) with different propositions. The optimum cutting conditions are obtained by using Taguchi's methodology are depth of cut at 0.06(mm), cutting speed at 46(m/min), feed rate at 0.10(m/rev), pressure 2.5(bar), stroke volume at 0.0033(cc), stroke time at 0.4(sec) and oil proportion factor at 0.25 (Qd) (75% of LRT and 25%of Rice bran oil). Cutting speed is the highly responsible to minimize the tool wear.**

***Keywords* — *Chip morphology, Minimum Quality Lubrication, Tool wear, Titanium alloy, Taguchi's methodology.***

## I. INTRODUCTION

Turning is one of the machining process in which the tool moves in longitudinal, transverse direction and work piece rotates at a pre described speed to produce a desired shape of the required part.

Titanium alloys are used in aerospace and many other applications (marine, medical, automotive, sports etc.) due to its high strength to weight ratio, better corrosion resistance and high temperature stability. But it has own limitations such as low thermal conductivity and high cutting temperatures so it is characterized under difficult-to-cut material [1]. While performing the turning operation with conventional tools, tool life is decreased progressively. In turning of titanium alloy lot of heat is produced at nose edge of the tool and this high temperature leads to rapid decrease in tool life. Coolants are used in turning of titanium alloy to lessen the temperature and to decrease the friction between work piece and cutting tool [2]. Conventional methods are implemented to enhance machinability and reduce the process cost. Cutting fluids are adopted such that it should penetrate tool to chip and work piece to tool mating area for removal of excess heat from cutting tool and proper chip flow. Moreover using of synthetic emulsions made of minerals leads to environmental damage and complicated to disposal and cleaning of work area [3]. Tool wear is influenced by chipping of cutting tool due to adhesion between work piece materials and cutting tool, it leads to fixing of chip to tool face due to chemical action between cutting tool and titanium material at high temperature [4]. Chip generation and it study plays a major role to understand the metal machining and produce important data for cutting process. In turning of titanium alloy segmented chips are generated, these chips are developed due to extension of cracks present in outer surface of the chip [5]. The mechanisms of chip generation are not fully developed till date. At present two theories are generally insisted to make clear the development of chip segmentation. First deals with adiabatic shear preferred by low thermal conductivity of the titanium alloy and second deals with crack initiation and propagation [6]. The chip-tool contract length is majorly having an effect on chip morphology and length of chip. Shorter tool chip contract area generate chip with less radius of curvature. The long segments of chips are found due to the chip do not contract with the chip-breaker feature of the tool. By applying high pressure coolants short chips are generated due to force of cutting fluids physically breaks the small parts. The longer chips redirect the flow of the coolants away from the chip which leads to shorter tool life. From this the shorter chip increases the tool life [7].

In this research work, Titanium alloy is used as work piece material and turning process performed with different proportions of blended cutting fluid are used to minimize

 DOI : 10.18231/2454-9150.2018.0150 

the tool wear by optimizing the process parameters under minimum quality lubricant with uncoated carbide tool. The chip morphology is also studied.

## II. EXPERIMENTATION

A. *Work Piece and Cutting Tools:*

Titanium alloy (Ti-6Al-4V) is chosen as the work piece. The chemical composition of Titanium alloy as shown in Table 1. Uncoated carbide tool is taken as the cutting tool for experimentation specification of tool is SNMG120408–MR4, 883. The tool holder used in machining is PSSNR2525M12.

Turning operation is performed in HMT NH 22 Lathe machine under minimum quantity lubrication. The MQL setup is VIP5 lubrication made by dropsa- makers system.

**Table 1: Chemical Composition of Ti-6Al-4V alloy**

| Material identification | Al | V | Fe | C | Ti |
|---|---|---|---|---|---|
| Diameter of 30 mm rod | 6.45 | 4.09 | 0.183 | 0.009 | REM |

B. *Cutting Fluids:*

The cutting fluids used in experimentation are Rice bran and LRT oil. These two oils are blended with different proportions. The proportions are, at first proportion 100% LRT oil, at second proportion 75% of LRT oil and 25% of Rice bran oil, at third proportion 50% of LRT oil and 50 % of Rice bran oil, at fourth proportion 25% and 75% of Rice bran oil, at fifth 100% of Rice bran oil.

C. *Experimental Procedure:*

Titanium alloy is machined in conventional lathe machine. Process parameters like Cutting speed, feed, depth of cut, pressure, stroke volume, stroke time and oil proportion factor are taken as control parameters. Each parameter is taken at five levels as given in Table 2. The experimental design is planned as per the Taguchi's method to optimization of cutting parameters by using $L_{50}$ orthogonal array under minimum quality lubrication. The smaller-the-better characteristics are taken to optimize the cutting parameters through analysis of means (ANOM). MINITAB software is used for analysis. Analysis of variance is done to find the process parameters that have significant effect on tool wear. Tool wear is measured using Tool maker's microscope. The obtained values are used for analysis. The chip thickness is measured by micro meter.

**Table 2 Levels and input parameters**

| Factor / level | Depth of cut (D) | Cutting speed (S) | Feed (F) | Pressure (P) | Stroke volume (SV) | Stroke time (ST) | Oil proportion factor (OPF) |
|---|---|---|---|---|---|---|---|
| 1 | 0.06 | 46 | 0.1 | 1.5 | 0.0033 | 0.2 | 0 |
| 2 | 0.16 | 63 | 0.16 | 2.5 | 0.0075 | 0.4 | 0.25 |
| 3 | 0.26 | 80 | 0.2 | 3.5 | 0.0125 | 0.6 | 0.5 |
| 4 | 0.36 | 97 | 0.28 | 4.5 | 0.0175 | 0.8 | 0.75 |
| 5 | 0.46 | 114 | 0.32 | 5.5 | 0.0225 | 1 | 1 |

## III. RESULTS AND DISCUSSIONS

A. *Optimization of parameters*

Using analysis of mean of Taguchi's method, the optimum process parameters are found as shown in Fig. 1. Thus the optimal process parameter obtained are depth of cut at 0.06(mm), cutting speed at 46(m/min), feed rate at 0.10(m/rev), pressure 2.5(bar), stroke volume at 0.0033(cc), stroke time at 0.4(sec) and oil proportion factor at 0.25(Qd) as shown in Fig 1. From the analysis of variance found that cutting speed as major contribution to minimize the tool wear as shown in Table 3.

Fuel consumption rate is calculated using equation (1)

Fuel consumption rate = stroke frequency x stroke volume (1)

= (1/stroke time) x stroke volume

= (1/0.4) x 0.0033 x 3600

= 29.70 ml/hr

The optimized fluid consumption rate to minimize the tool wear is 29.70 ml/hr.

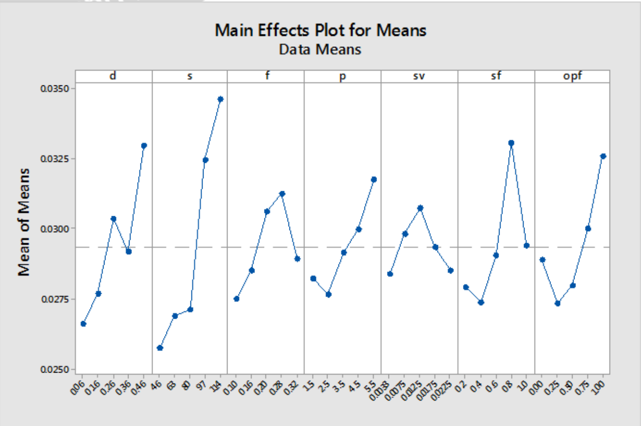


**Fig. 1 Analysis of Mean for Tool wear**

B. *Chip Morphology*

While turning of titanium alloy majorly two different types of chips obtained. The long washer helical chips and

 DOI : 10.18231/2454-9150.2018.0150 

*ISSN : 2454-9150* Vol-04, Issue-02, May 2018

snarled washer type helical chips. These types of chips generated due to shearing of the specimen material along primary shear zone.

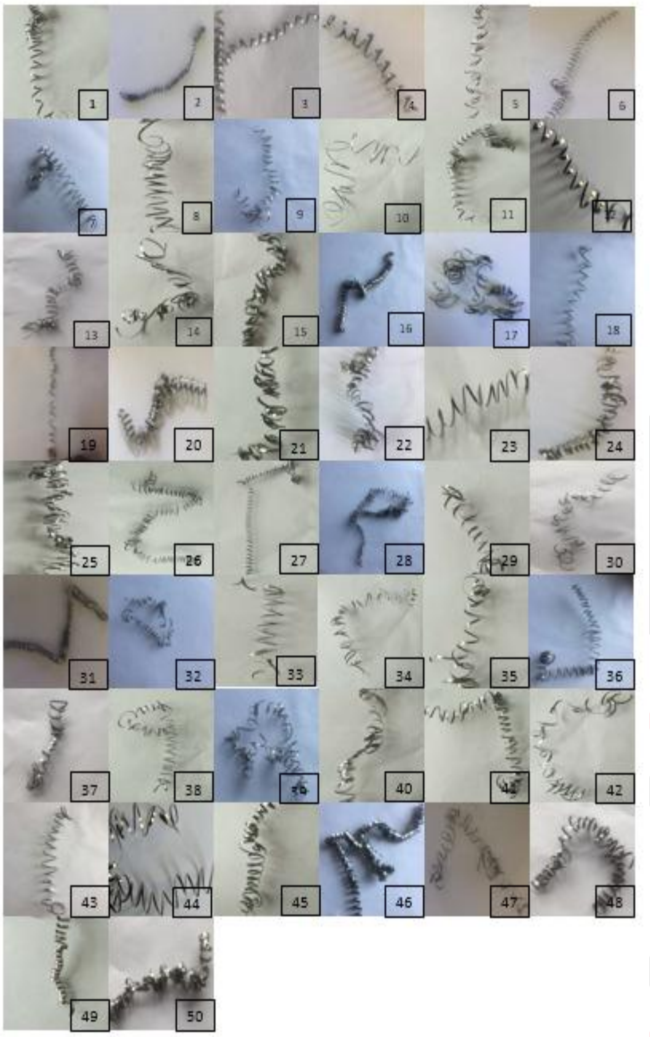

**Fig.2: Chip morphology of Ti-6Al-4V alloy during turning at different machining conditions.**

**Table 3 Summary of ANOVA for Tool wear**

| Source | DF | Adj SS | Adj MS | F-value | Contribution |
|---|---|---|---|---|---|
| D | 4 | 0.000284 | 0.000071 | 72.35 | 17.1601208 |
| S | 4 | 0.000665 | 0.000166 | 169.38 | 40.1812689 |
| F | 4 | 0.000119 | 0.00003 | 3022 | 7.19033233 |
| P | 4 | 0.000167 | 0.000042 | 42.42 | 10.0906344 |
| SV | 4 | 0.000042 | 0.00001 | 10.61 | 2.53776435 |
| SF | 4 | 0.000184 | 0.000046 | 46.82 | 11.1178248 |
| OPF | 4 | 0.000173 | 0.000043 | 44.13 | 10.4531722 |
| Error | 21 | 0.000021 | 0.000001 | | 1.26888218 |
| Total | 49 | 0.001655 | | | 100 |

These chips are unsuitable for continuous machining because machining should stop frequently to remove the chip from machining area. Moreover long chips deviates the coolant path direction away from the tool to work piece which tends to rapid tool wear. Decreasing the feed rate and increase depth of cut many changes form of chip generation. It includes increases of chip thickness and shortens the distance between the chips and increases in the angle of shear band. The chip thickness is measured for 50 experiments that were sectioned perpendicular to width of the chip using micro meter. The images of each chip are shown in Fig 2. Long continuous chips are produced during machining of Titanium alloy has increases the tool wear due to it deviates the flow of coolants away from cutting tool to chip contract area which leads to increase of high temperature between tool to work piece contract area.

## IV. CONCLUSIONS

The aim of the work is to minimize the quantity of coolant, to promote the tool life and study chip formation in turning of Titanium grade5 alloy.

The optimal process parameter obtained from analysis of mean are depth of cut at 0.06(mm), cutting speed at 46(m/min), feed rate at 0.10(m/rev), pressure 2.5(bar), stroke volume at 0.0033(cc), stroke time at 0.4(sec) and oil proportion factor at 0.25(Qd) (75% of LRT oil and 25% of Rice bran oil)

From the analysis of variance found that cutting speed parameter as a major effect to minimize the tool wear in uncoated carbide tools.

It found that optimal flow rate is 29.7 ml/hr to get better tool wear while turning of titanium alloy using uncoated carbide tools

Coolants at 75 % of LRT and 25 % of Rice bran oil proportion are suitable for machining of titanium alloy to minimize the tool wear of uncoated carbide tool.

Long continuous chips are produced during machining of Titanium alloy has increases the tool wear due to it deviates the flow of coolants away from cutting tool to chip contract area which leads to increase of high temperature between tool to work piece contract area.

## REFERENCES

[1] Nithyanandam, J., Sushil Lal Das, and K. Palanikumar, "Influence of cutting parameters in machining of titanium alloy." Indian Journal of Science and Technology 8, no. S8 (2015): 556-562.

[2] Pervaiz, Salman, Amir Rashid, Ibrahim Deiab, and Cornel Mihai Nicolescu, "An experimental investigation on effect of minimum quantity cooling lubrication (MQCL) in machining titanium alloy (Ti6Al4V)." The International Journal of Advanced

 DOI : 10.18231/2454-9150.2018.0150 

Manufacturing Technology 87, no. 5-8 (2016): 1371-1386

[3] Sartori, S., A. Ghiotti, and S. Bruschi, "Hybrid lubricating/cooling strategies to reduce the tool wear in finishing turning of difficult-to-cut alloys." Wear 376 (2017): 107-114.

[4] Koseki, Shuho, Kenichi Inoue, Katsuhiko Sekiya, Shigekazu Morito, Takuya Ohba, and Hiroshi Usuki, "Wear mechanisms of PVD-coated cutting tools during continuous turning of Ti-6Al-4V alloy." Precision Engineering 47 (2017): 434-444.

[5] Sun, S., M. Brandt, and M. S. Dargusch, "Characteristics of cutting forces and chip formation in machining of titanium alloys." International Journal of Machine Tools and Manufacture 49, no. 7-8 (2009): 561-568.

[6] Sutter, Guy, and Gautier List, "Very high speed cutting of Ti–6Al–4V titanium alloy–change in morphology and mechanism of chip formation." International Journal of Machine Tools and Manufacture 66 (2013): 37-43

[7] da Silva, Rosemar B., Álisson R. Machado, Emmanuel O. Ezugwu, John Bonney, and Wisley F. Sales," Tool life and wear mechanisms in high speed machining of Ti–6Al–4V alloy with PCD tools under various coolant pressures." Journal of Materials Processing Technology 213, no. 8 (2013): 1459-1464.

[8] Viharos, Zsolt János, Sándor Markos, and Csaba Szekeres. "ANN-based chip-form classification in turning." In Proceedings of the XVII. IMEKO World Congress–Metrology in the 3rd Millennium, pp. 1469-1473. 2003.

[9] Balaji, J. H., V. Krishnaraj, and S. Yogeswaraj. "Investigation on high speed turning of titanium alloys." Procedia Engineering 64 (2013): 926-935.

 DOI : 10.18231/2454-9150.2018.0150 